NASA’s Integrated Space Communications Architecture

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SPACE COMMUNICATIONS AND NAVIGATION

Keeping the universe connected.

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  - Integrated Network Management
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    - Lunar Relay & Mars Relay
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- **Summary**

Background

- In 2006, NASA Administrator assigned roles and responsibilities for the Agency's space communications and tracking assets to the SCaN Office
- This mandate centralized the management of NASA's space communications and navigation networks: the Near Earth Network (NEN), the Space Network (SN), and the Deep Space Network (DSN)
- In a September 2007 memo, the Associate Administrator described the concept of an integrated network architecture
- The new SCaN integrated network architecture is intentionally capability-driven and will continue to evolve as NASA makes key decisions involving technological feasibility, mission communication needs, and funding
- It also illustrates the progression and the planned transformation from the current configuration of loosely coupled networks into a single, unified, integrated network
- This presentation summarizes the evolution of the integrated network architecture of NASA's communication and navigation infrastructure

NASA Level 0 Requirements (Baselined on January 28, 2010)

- SCaN shall develop a unified space communications and navigation network infrastructure capable of meeting both robotic and human exploration mission needs
- SCaN shall implement a networked communication and navigation infrastructure across space
- SCaN's infrastructure shall provide the highest data rates feasible for both robotic and human exploration missions
- SCaN shall assure data communication protocols for Space Exploration missions are internationally interoperable
- SCaN shall provide the end space communication and navigation infrastructure for Lunar and Mars surfaces
- SCaN shall provide communication and navigation services to enable Lunar and Mars human missions
- SCaN shall continue to meet its commitments to provide space communications and navigation services to existing and planned missions

Architectural Goal and Challenges

Goal

To detail the high level SCaN integrated network architecture, its elements, architectural options, views, and evolution until 2025 in response to NASA's key driving requirements and missions. The architecture is a framework for SCaN system evolution and will guide the development of program requirements and designs.

Challenges

- Forming an **integrated** network from three pre-existing individual networks
- Resource constraints
- Addressing **requirement**-driven, **capability**-driven, and **technology**-driven approaches **simultaneously**
- **Interoperability** with U.S. and foreign spacecraft and networks
- **Uncertainty** in timing and nature of future communications mission **requirements**
- Requirements for **support** of missions already in **operation**, as well as those to which support commitments have already been made
- Changes in high level requirements and direction

SCaN Current Networks

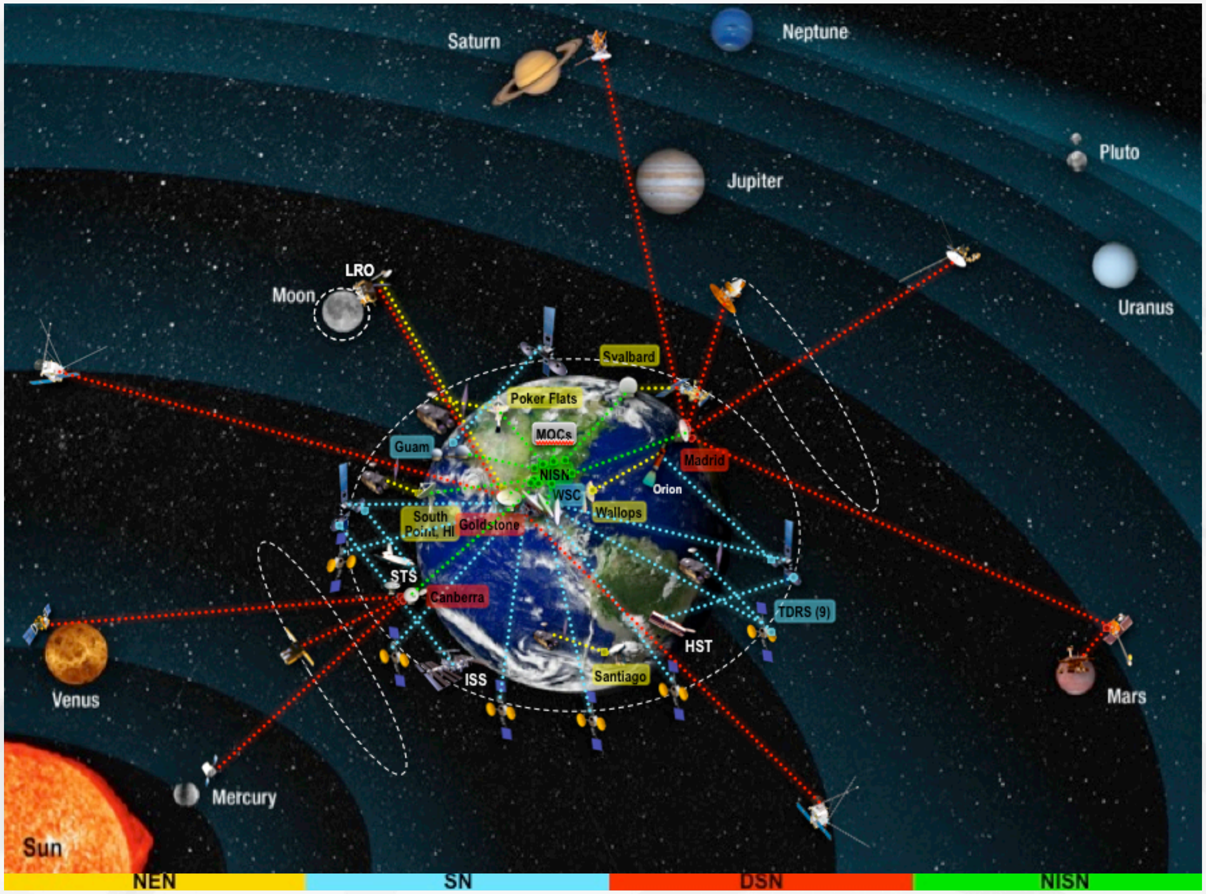
The current NASA space communications architecture embraces three operational networks that collectively provide communications services to supported missions using space-based and ground-based assets.

Near Earth Network - NASA, commercial, and partner ground stations and integration systems providing space communications and tracking services to orbital and suborbital missions

Space Network - constellation of geosynchronous relays (TDRSS) and associated ground systems

Deep Space Network - ground stations spaced around the world providing continuous coverage of satellites from Earth Orbit (GEO) to the edge of our solar system

NASA Integrated Services Network (NISN) - not part of SCaN; provides terrestrial connectivity



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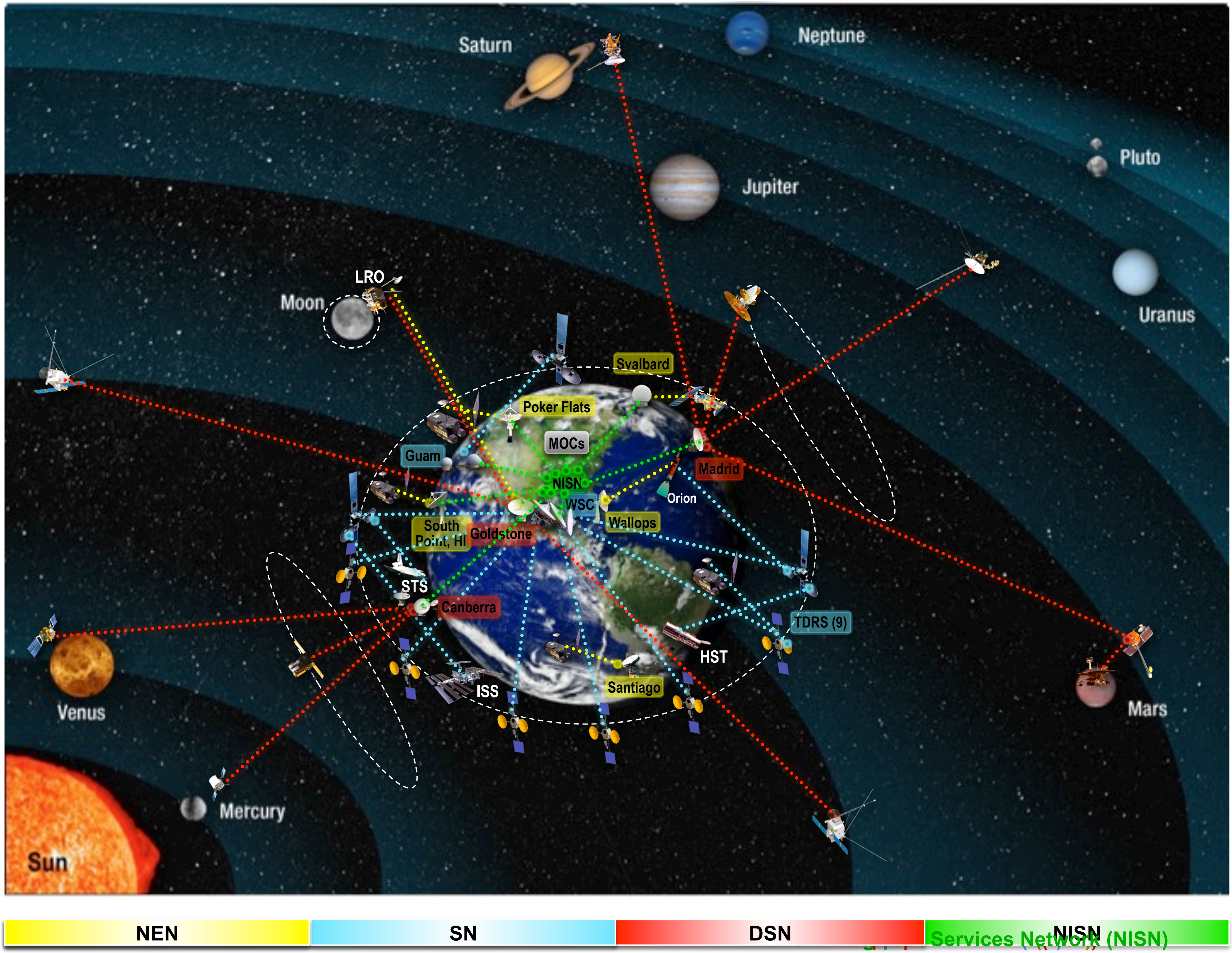
Saturn
Neptune
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Svalbard
Poker Flats
MOCs
Guam
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Orion
WSC
Wallops
South Point, HI
Goldstone
STS
Canberra
TDRS (9)
HST
Santiago
ISS
Venus
Mars
Mercury
Sun
NEN
SN
DSN
NISN
Services Network (NISN)

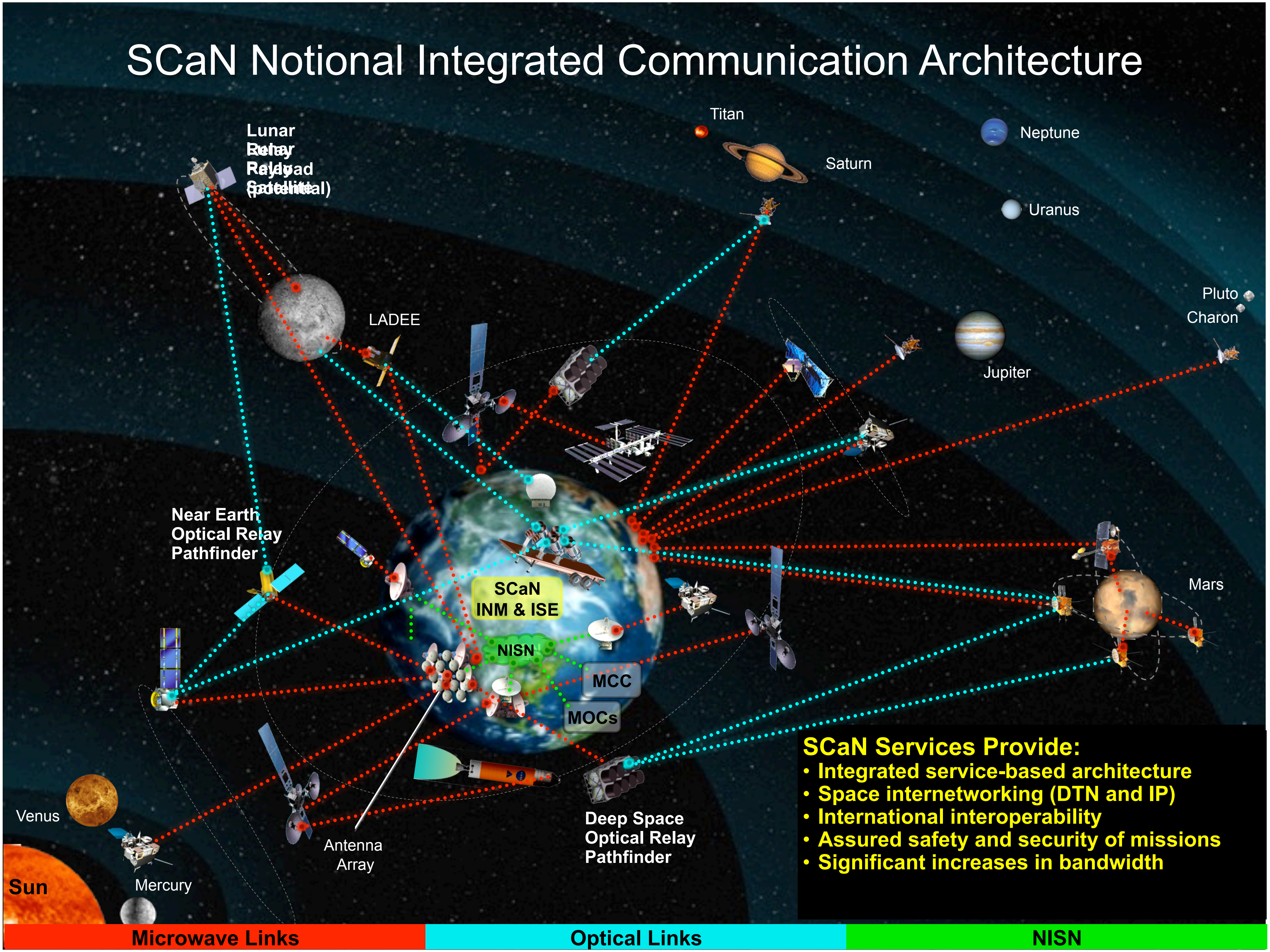
Key Requirements, Mission Drivers, and Capabilities Flowdown

Today | 2015 | 2018 | 2025+

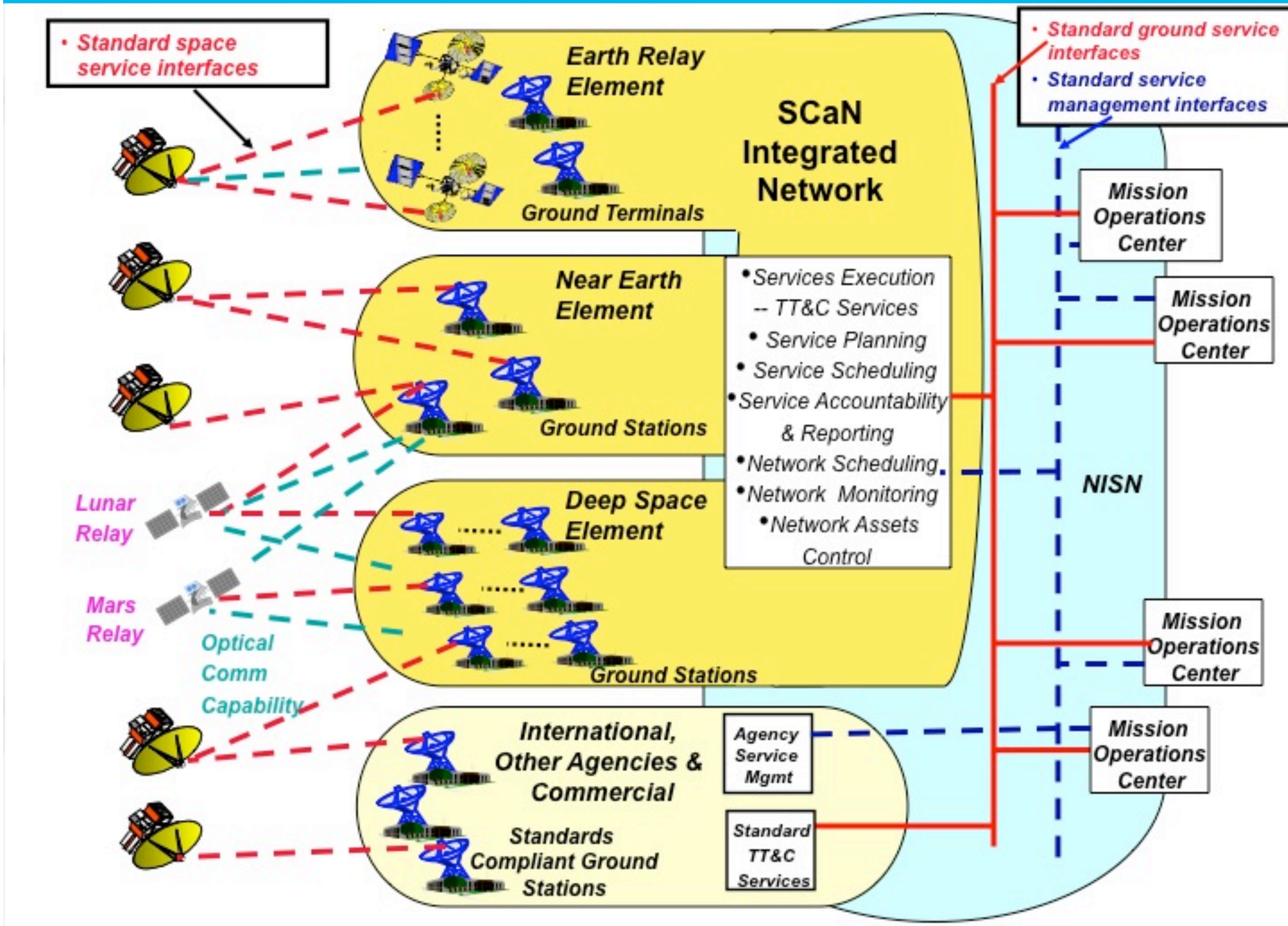
Level 0 Requirements

- Provide space communications and navigation services to existing and planned missions.
- Develop a unified space communications and navigation network infrastructure
- Implement internationally interoperable communication protocols
- Provide the highest data rates technically and financially feasible
- Implement a networked communication and navigation infrastructure across space
- Provide anytime/ anywhere communication and navigation services for Lunar and Mars human missions

	Today	2015	2018	2025+
Mission Drivers	• Shuttle/ISS • Mars Landers • Great Observatories • Coordinated Earth Observation • LRO	• Commercial/Orion/ISS • Mars – Coordinated and Complex Science Missions • Lunar Robotic Missions • High Data Volume Hyper Spectral Missions • SAR Earth Observation	• Multiple Cooperating Robotic Missions • Outer Planet – 1	• Hyper spectral imaging at Mars and beyond • Human Lunar Missions • Earth Sensor Web • Mars Exploration • Mars Sample Return
Capabilities	• Up to 300 Mbps (SN) • Up to 150 Mbps (NEN) • Up to 6 Mbps at 1 AU • Radiometric Services	• Up to 1.2 Gbps (SN/NEN) • Standard TT&C Services • Up to 150 Mbps (DSN) – 1 AU • Radiometric Enhancements	• Integrated Network Management • Integrated Service Execution • Space Internetworking	• Up to 1.2 Gbps from the moon (optical) • Optical Communications to 100 Mbps (planetary) • Lunar far side coverage • High capacity multi-node • Inter-networking interoperability


SCaN Notional Integrated Communication Architecture
Lunar Relay Payload (potential)
Lunar Relay Satellite
Titan
Neptune
Saturn
Uranus
Pluto
Charon
LADEE
Jupiter
Near Earth Optical Relay Pathfinder
SCaN INM & ISE
NISN
MCC
MOCs
Mars
Venus
Mercury
Sun
Antenna Array
Deep Space Optical Relay Pathfinder
SCaN Services Provide:
• Integrated service-based architecture
• Space internetworking (DTN and IP)
• International interoperability
• Assured safety and security of missions
• Significant increases in bandwidth
Microwave Links
Optical Links
NISN

SCaN Integrated Network Service Architecture



SCaN Integrated Network Services

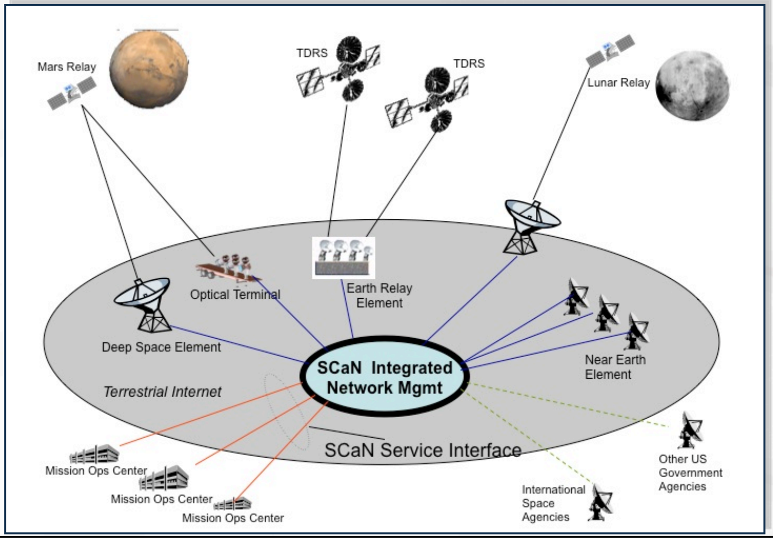
The NASA SCaN infrastructure will provide four categories of standard services to its customers:

1. **Forward data delivery services**
   - Forward Command Link Transmission Unit (CLTU) service
   - Forward transfer frame service
   - Forward internetworking and file services
2. **Return data delivery services**
   - Return all frames service
   - Return channel frames service
   - Return internetworking and file services
   - Return unframed telemetry service
3. **Radiometric services**
   - Raw and Validated radiometric data
   - Delta- Differential One-way Ranging
4. **Position and Timing services**
   - Time distribution
   - Trajectory determination and prediction
5. **Specialized services**
   - Unique services (e.g., radio science)
   - Legacy services

Integrated Network Management

Mission/Program Drivers

- **ESMD missions** and many near-Earth **SMD missions** require the services of multiple SCaN network assets
  - Seamless interfaces for service requests to missions is critical
- SCaN Program calls for the **Integrated Service Architecture** requiring common service management across all assets for:
  - Maximum operations efficiency
  - O&M cost reduction



Infrastructure Enhancements

- **Standard service management** functions:
  - Service planning
  - Service request scheduling
  - Service accountability reporting
- **Common network control** functions:
  - Network scheduling
  - Network asset configuration and control
  - Network asset monitoring
  - Space Internetworking management
- **SCaN Services Catalog** with standard services across NASA's Integrated Network & other participating providers

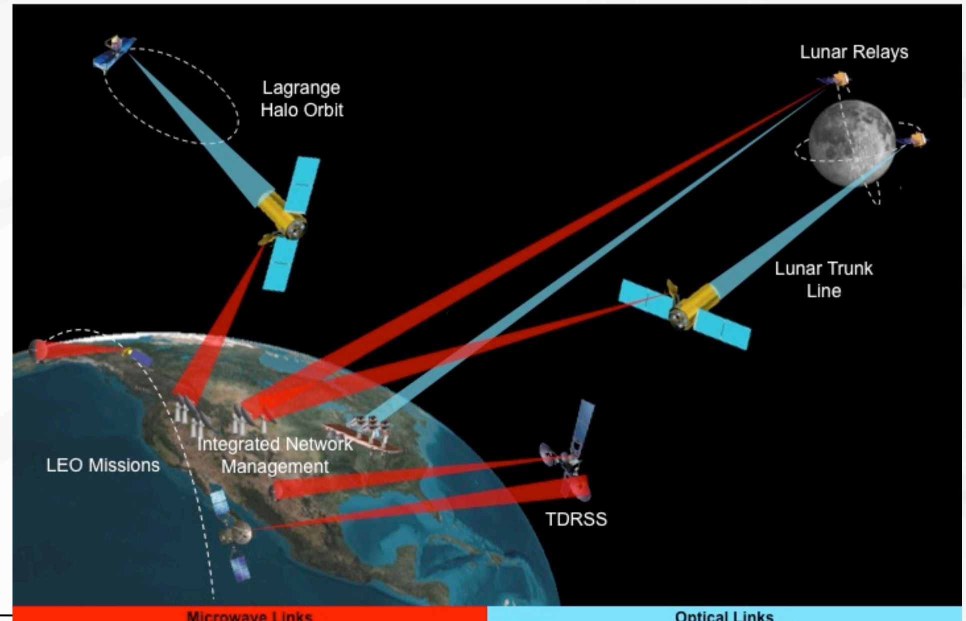
Performance

- Service management interface in compliance with CCSDS standards
  - Maximum **interoperability** between SCaN network elements and with assets operated by international partner agencies
- Maximum **commonality** in service management and network control among network assets
- The network management function dispatches mission user requests to and interacts with individual SCaN networks assets:
  - Reduced **user burden**
  - Ensured **access security** to TT&C services via tunneling and VPN
- Enables integrated **service commitment process**

Enhanced Near Earth Domain Capabilities

Mission/Program Drivers

- **Lunar robotic missions**: high-rate return link
- **Orion ISS mission**: robust communication for human flight/safety
- **Human Lunar missions**:
  - Highly reliable TT&C links;
  - High-rate trunk line;
  - Near continuous tracking coverage;
  - Seamless mission support by all network assets
- **JWST and JDEM:** high-rate science data return at L2 distance
- **Earth Sensor Web**: Space Internetworking
- **Integrated network**: common services, service interfaces, and service management for interoperability (international and U.S.)
- **Higher data rates** to enable new missions and increase operations efficiency



Infrastructure Enhancements

- **Optical IOC:** flight and ground terminals
- **Earth Orbiting Optical Relay** for higher availability
- **RF Ground Stations**
  - Capacity and performance upgrade
- **TDRSS**
  - TDRS M&N
  - Multiple aperture arraying
  - TDRSS navigation beacon (TASS)
- **Space Internetworking Nodes**
- **Lunar Relay Satellites**
- **Integrated Network Management and Integrated Service Execution**

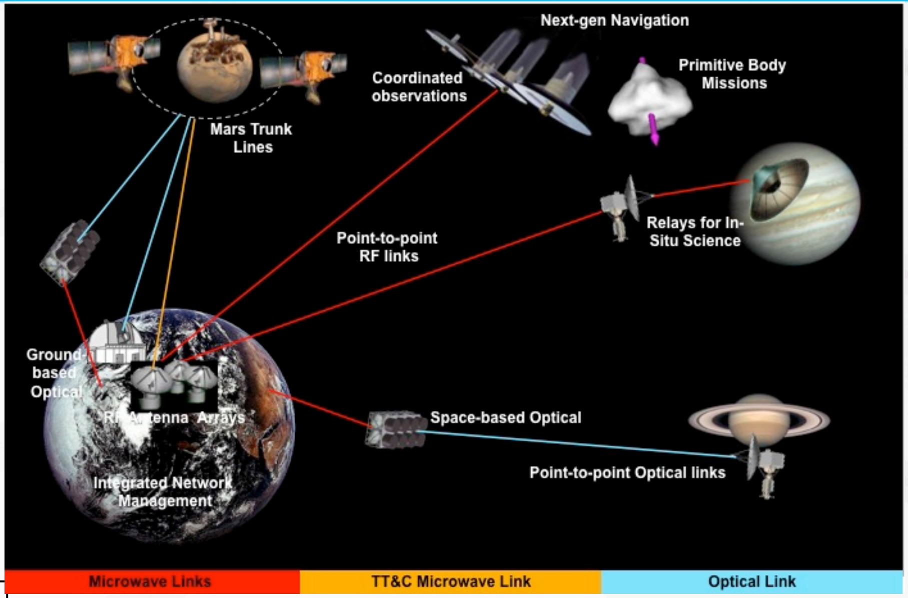
Performance

- **Near-Earth Optical IOC**
  - Up to 1.2 Gbps return link; 100 Mbps forward
- **RF return link enhancement**
  - At least 150 Mbps at L2 using Ka-band
  - At least 1.2 Gbps for LEO/MEO using Ka-band
- **RF forward link enhancement**
  - 25 ~ 70 Mbps for LEO through Lunar using Ka-band
- **Anytime, anywhere connectivity** within Earth line of sight; Global Earth coverage
- **Standard services** across the network

Enhanced Deep Space Domain Capability

Mission/Program Drivers

- **Mars Sample Return**: higher radiometric accuracy for precision rendezvous and docking
- **MAVEN:** Extends reliable communications for Mars relay
- **Mars Science Orbiter:** Mars relay and high-rate trunk line
- **Outer Planetary (OP-1)**: long distance link to Jovian or Saturnian spacecraft; survival-time limited missions
- **New Frontiers:** extreme distance return link and emergency TT&C
- **Integrated network**: common services, service interfaces, and service management for interoperability (international and U.S.)
- **Higher data rates** to enable new missions and increase operations efficiency



Infrastructure Enhancements

- **Optical IOC:** flight and ground terminals
- **Deep Space Optical Relay** for higher availability
- **RF Ground Stations**
  - 70m replacement with antenna array
  - Capacity and performance upgrade
- **Space Internetworking Nodes**
- **Integrated Network Management and Integrated Service Execution**

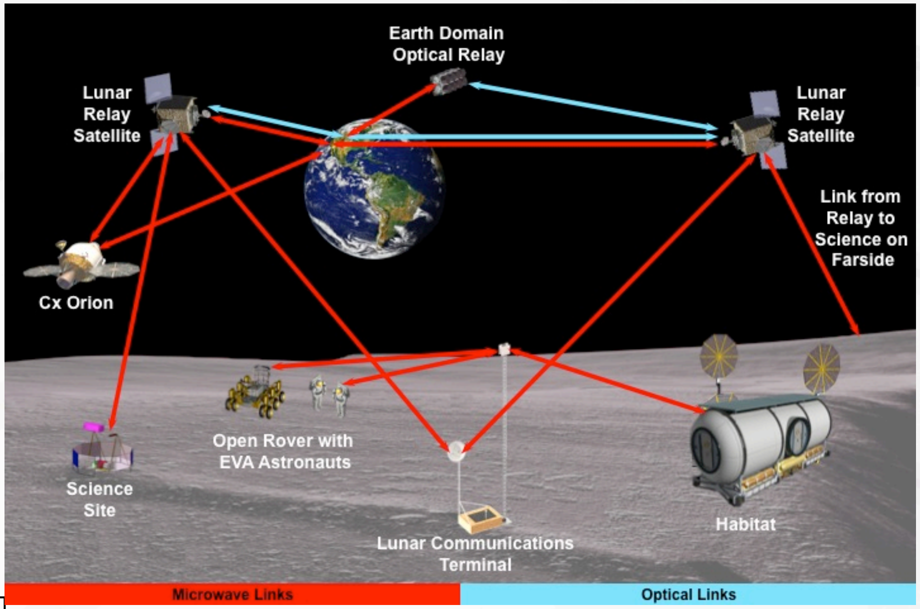
Performance

- **Deep Space Optical IOC**
  - 100 Mbps extensible to 1Gbps return link at 1AU; $\geq$ 2 Mbps forward
- **RF enhancement for return link**
  - Predominant use of deep space Ka for data return
- **New tracking data types for navigation support**
  - Ka uplink/downlink
  - Optimetric uplink/downlink (IOC)
- **Robust, Scalable RF** (Array of antennas)
- **Anytime, anywhere connectivity** within Earth line of sight
- **Robust emergency X-band TT&C**
  - Robust high-power uplink capability
- **Standard services** across the network

Lunar Relay Capability

Mission/Program Drivers

- **Lunar Science:** International Lunar Network (ILN) Landers starting in 2018
- **Lunar Exploration:** Altair first lander test in 2022; Human Lunar Return ("Boots on the Moon") in 2023; Initial Lunar Outpost complete in 2025
- **Minimize the mass and power** communications needs on users
- **Navigation aids** to enable precision landings in habitat zone
- **Enable Control and monitoring** of lunar assets from Earth or by astronauts



Infrastructure Enhancements

- Lunar Relay Satellites (LRS)
- Ground Systems for LRS control
- Space Internetworking Nodes
- Integrated Network Management and Integrated Service Execution

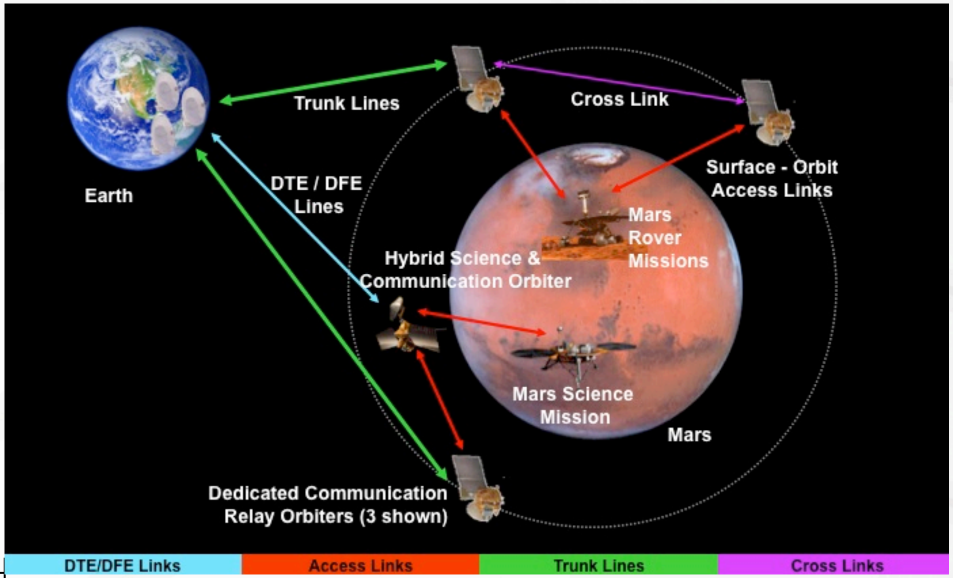
Performance

- **Scalable** architecture providing 60-100% coverage
- Over **1.2 Gbps optical** link from the Moon; 20 Mbps uplink from Earth to the Moon
- At least **250 Mbps** by RF links from the lunar vicinity
- **Radiometric** capabilities for **precision approach and landing** with less than **100m** positioning uncertainty; **support for surface roving**

Mars Relay Capability

Mission/Program Drivers

- **Mars Exploration**
  - Science orbiters
  - Science landers and rovers
  - Mars sample return
- **Human Exploration Pre-cursor**
  - Dedicated Mars comm / relay orbiters
  - Mars communication terminal



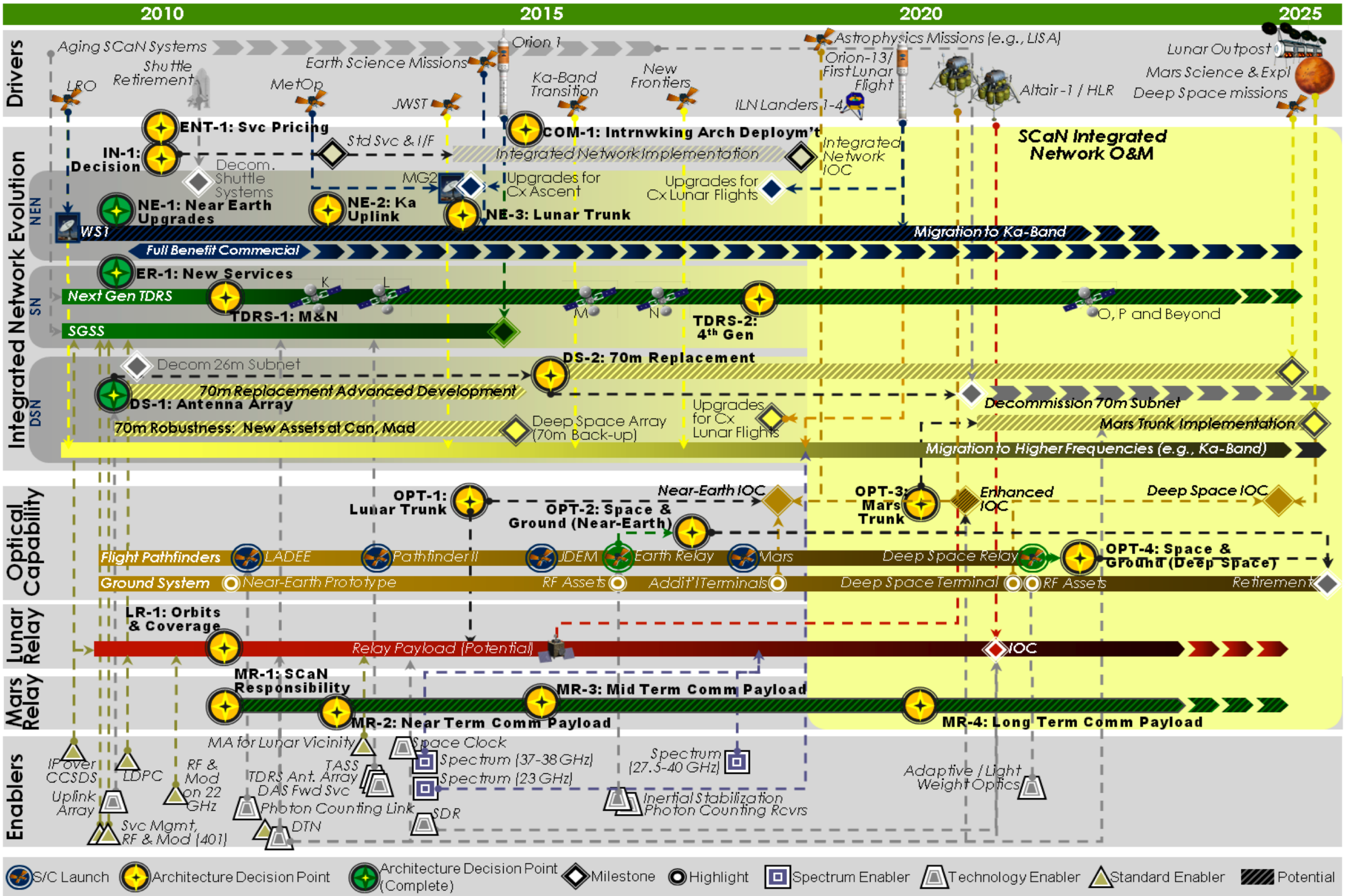
Infrastructure Enhancements

- **Hybrid Science / Comm Orbiters:** relay payloads on science spacecraft
  - Telecommunications, data relay, navigation, and timing services
  - Store & forward file and initial space internetworking
- **Dedicated Comm / Relay Orbiters:** scaled for higher availability
  - Extended space internetworking services
- **Space Internetworking Nodes**
- **Integrated Network Management and Integrated Service Execution**

Performance

- **Scalable** architecture that can easily evolve to support human exploration phase
- Up to 6 Mbps **RF** data rates for near-term; Up to **150 Mbps** in long-term
- Potential for **optical** Trunk to Earth receivers (at least **100 Mbps @ 1 AU** return and 2 Mbps forward, extensible **up to 1 Gbps**)
- Can support **Earth-like** science around Mars
- **Radiometric** capabilities for **precision approach, landing, and surface roving**
- Forms a subnet of the DTN **Space Internetworking for coordinated Mars exploration**

SCaN Integrated Network Roadmap



Summary

SCaN has defined an Integrated Network Architecture that fully meets the Administrator's mandate to the Program, and will:

- Evolve over time to continue to meet NASA mission directorates and external agencies mission requirements
- Enable future NASA missions requiring advanced communications and tracking capabilities
- Simplify mission interfaces and increase SCaN operational efficiency through standardization, commonality, and technology infusion

Backup

Background: Excerpts from SCAN Program Commitment Agreement (signed Oct 18, 2008)

1. SCaN PROGRAM OBJECTIVES

SCaN Program goals are derived from the NASA Strategic Plan and the subordinate tactical plans of the Mission Directorates

5. SCaN Planning:
Evolve the SCaN services in a manner consistent with a space architecture framework and mission requirements

Pursue cooperation, collaboration, and cross-support with industry, other Government agencies, and international space agencies

2. SCaN PROGRAM OVERVIEW

SCaN is responsible for providing communications and navigation services, including systems engineering and planning, to flight missions and for supplying terrestrial communications services.

SCaN is responsible for maintaining and evolving the SCaN architecture to effectively and efficiently meet flight missions' present and future needs.

4. TECHNICAL PERFORMANCE COMMITMENT (excerpt) - The SCaN Program shall:

1.Provide the Agency with space communication and navigation services and global terrestrial communication services.

2.Examine NASA goals, initiatives, and missions to **identify future communication needs**.

3.Establish and manage a set of projects that accomplish SCaN program objectives within allocated resource and schedule constraints with priority on safety, mission success, and risk management.

4.Evolve the SCaN elements into an integrated "network of networks."

5.Develop, operate, and maintain SCaN program assets and resources in a manner to achieve **best value** for the Agency.

7. Develop policy and provide planning, coordination, and representation to secure and protect necessary electromagnetic spectrum and evolve efficient and interoperable telecommunications standards in support of the Agency's needs.

8. Establish a **telecommunications technology program** that advances the effectiveness and efficiency of SCaN elements and services.